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**Research Article**

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# Determination of Structural Properties and Heating Load of Greenhouses to be Established in Edirne Province Ipsala Region

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**Abstract** The present study aims to determine certain structural features and calculate the heating load of the greenhouses to be established in the Ipsala region of Edirne province in the Thrace part of Turkey. At the end of the study, it has been suggested that the single greenhouses be positioned in the east-west direction and the block greenhouses in the south-north direction to maximize the utilization of solar energy for the greenhouses to be built in the region. When choosing the greenhouse construction and conducting cross-section checks on the carrier elements, it is appropriate to consider a dynamic wind load of 58.9 kg/m$^2$ and a snow load of 50-75 kg/m$^2$. The height of the greenhouse side wall should be between 2.0-3.0 m, and the roof slope angle should be between 26-30°. Double-layer glass or double-layered rigid plastic with the highest thermal conductivity resistance should be used as greenhouse cover material in the region. Heating greenhouses can be accomplished by using heating pipes put on the greenhouse floor or air blower systems connected to perforated ducts. Rice husks, which are produced by processing the rough rice in the region, should be used as fuel in heating.

**Keywords** Greenhouses, Structural features, Heating load, Degree-days number, Rice husks

## Introduction

Rapid population growth, the need to provide employment for this growing population, and the awareness and recognition that industrialization is necessary to raise people's living standards have resulted in an increase in industrial investment across the country. This phenomenon has led to a considerable portion of the Thrace lands being covered with industrial facilities, a process that is continuing at a rapid pace. The transition from the agricultural ecosystem to the industrial ecosystem has brought along some environmental problems. Among these environmental problems are water and soil pollution. The Ipsala region has an important place in rough rice production in Turkey, with its annual yield exceeding 165 000 tons [1]. However, in recent years, excessive pollution caused by rapid urbanization and industrialization, especially soil and water resources, has increased significantly in the Thrace region. It is clear that this situation will adversely affect the rough rice production by causing an increase in the pollution load of the Meriç and Ergene Rivers, which are the most important surface water resources in the region and are widely used in agricultural irrigation, especially in the irrigation of rice, which is one of the traditional products of the region. On the other hand, the development of mechanization in rough rice production has reduced the need for labor. In order to eliminate all these negativities and to ensure the sustainability of agricultural production, it is important for the region to develop greenhouse cultivation as an alternative product in addition to rough rice production in the Ipsala region and to support the studies to be carried out on this subject.

A greenhouse is briefly defined as "the facilities where vegetable growing and floriculture are carried out economically all year round, regardless of climate." One of the most important problems of keeping the population in rural areas in our country is the size of the land capital. On the other hand, the disappearance of agricultural lands for various reasons or their shrinkage by division by inheritance forces farmers to seek alternative production. The greenhouse is currently seen as the first of the measures to prevent unplanned urbanization by keeping the population in rural areas, reducing unemployment, and ensuring that more products are purchased. This study aimed to determine certain structural features and to calculate the heating load of the greenhouses to be established in the Ipsala region of Edirne province in the Thrace part of Turkey.

**Material and Method**

The research area was the Ipsala district, with a surface area of 753 km², in Edirne province, located in the Thrace region of Turkey. The latitude of the district is 40 $^{o}$ 56', the longitude is 26 $^{o}$ 24' and its altitude above sea level is 10 m [2]. Although the Ipsala region is located in the Mediterranean climate zone, the characteristic features of the continental climate are dominant in the region. According to multi-year meteorological observation data, the annual average temperature is 14.0 ℃, annual total precipitation is 627.3 mm, annual average relative humidity is 76%, annual total evaporation amount is 922.5 mm, annual maximum wind speed is 30.7 m/s, annual average sunshine duration is 6.5 hours, the annual average daily radiation intensity is 155.4 W/m$^2$ h. In winter, the average daily radiation intensity is 75.2 W/m$^2$h. The number of days covered with snow in the region has been 10.9, and the highest snow thickness has been measured to be 50 cm. [3].

The technical information and principles given in Filiz [4], Ozturk [5] and Yuksel [6] have been used to determine the location, positioning, and structural features of the greenhouses for the research area and obtain the basic data about the heating systems. The heating load of the greenhouses to be established was determined with the help of the following equation given in Yuksel [6] based on the number of degree-days.

$$Q = 24 \times U \times G \times A/\eta \quad (1)$$

where Q is the annual heat requirement of the greenhouse (W/year); U isthe heat transfer coefficient (W/m$^2$ ℃); G is the number of degrees-days; A is the outer surface area of the greenhouse (m$^2$); η is the efficiency of the heating system (70%).

The heat transmission coefficient (U) was calculated with the help of the following equations, based on the situation of the greenhouse against the wind and the heating methods used in the heating of the greenhouses.

$$U = \frac{1}{R} \quad (2)$$

$$R = R_i + R_\lambda + R_d \quad (3)$$

where R is the total heat transfer resistance (m$^2$℃/W); $R_i$ is the inner surface thermal resistance of the greenhouse cover (m$^2$ ℃/W); $R_\lambda$ is the thermal resistance of greenhouse cover materials (m$^2$ ℃W); $R_d$ is the outer surface thermal resistance of the greenhouse cover (m$^2$ ℃/W).

In the light of the obtained data and literature information, the annual heating load for the greenhouse with 1000 m$^2$ cover surface, which can be done in the research area, has been calculated separately for the cases of using different cover materials

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**Results and Discussion**

**Structural properties the greenhouses to be established in Ipsalaregion**

Factors such as climate, availability, and quality of irrigation water, electrification, topographic structure and soil characteristics, transportation opportunities, labor supply, and the presence of natural hot water resources are taken into consideration in the selection of greenhouse location [4], [9]. The Ipsala region consists of topographically flat and nearly flat, slightly undulating lands. Rough rice is produced intensively on flat agricultural lands that can be irrigated in the region. Thus, lands in the region that are incapable of producing rough rice or are unsuitable for field cultivation might be utilized as greenhouse areas. Especially, south-facing sloping lands, not exposed north winds, should be preferred. In addition, it is appropriate to have a slope of 0.5-1.5% in the area where the greenhouse will be established [6]. The development and spread of greenhouse agriculture in the Ipsala region will be examined, particularly on barren soils where conventional agriculture is impossible.

The placement direction of the long axis of a greenhouse has an effect on the rate of benefiting from the sun's rays. As the latitude increases in the northern hemisphere, the angle of incidence of the sun's rays decreases.

When the multi-year meteorological data of the Ipsala region are examined, the average sunshine duration in September, October, and November is 5.5 hours, the average global sunshine intensity is 121.4 $W/m^2$ h, the average sunshine duration is 3.1 hours in December, January, and February, the average global sunshine intensity is 75.2 $W/m^2$ h, the average sunshine duration in March, April, and May is 6.7 hours, and the average global sunshine intensity is 183.5 $W/m^2$ h is [3]. To maximize the duration and intensity of sunlight, which is critical for reducing greenhouse heating costs and for the vegetative and generative development of plants, the long axis of individual greenhouses in the Ipsala region should be oriented east-west, and the wide-span block greenhouses should be oriented north-south, to minimize the shading effect. In addition, there should be a shading interval of 30% of the floor area between adjacent greenhouses. Considering the direction and number of prevailing winds, which are extremely effective at reducing heat loss through infiltration in greenhouses during the winter and transition seasons, as well as the region's topographic structure, windbreaks should be established in the areas where greenhouses are established, at a distance that avoids shadowing.

Greenhouse width is planned as multiples of 3 (3-6-9-12-15 m) in single greenhouses, depending on the greenhouse type. In block greenhouses, the width of the greenhouse can be increased up to 100-200 m, provided that there is a wide road in the middle. The length of the greenhouse should not exceed 50 m in a single greenhouse with natural ventilation in order for the ventilation to work effectively. In block greenhouses, the length of the greenhouse can be increased up to 100-110 m, provided that the ventilation is sufficient. The height of the greenhouse side wall varies between 1.8–4.0 m [8], [6]. Since the terrestrial climate features are effective in the Ipsala region, the height of the sidewall of the greenhouse should be kept between 2.0-3.0 m to keep the indoor climate conditions at an optimum level and reduce the heating costs in winter and transition seasons. In our country, the angle of inclination of the roof should be taken between 26°-30° depending on the angle of incidence of the sun rays [6]. Considering the climatic conditions of the region, the amount of space required for natural ventilation in greenhouses should be 15-20% of the greenhouse floor area. For an effective ventilation, a ventilation window must be made in the ridge. The opening angles of the windows to be built in the ridge should be at least 15°horizontally. The opening angle of the windows to be placed on the lateral surfaces should be at least 65° vertically.

Considering the maximum wind speed of 30.7 m/s, which is effective in the region, a dynamic wind load of 58.9 $kg/m^2$should be taken into account while selecting the greenhouse construction and making cross-sectional controls on the bearing elements. Again, considering the meteorological data as snow load calculation, a load of 50-75 $kg/m^2$ should be taken into account, depending on the greenhouse roof shape and roof slope angle.

**Determination of heating load in greenhouses to be established in Ipsala region**

There are different approaches in determining the annual heating load in greenhouses. Among these approaches, the number of degree-days method stands out. The method's degree-days are calculated using long-term meteorological observations of days where the outside air temperature is less than 12 ℃ and the temperature within the greenhouse is 19 ℃ [6]. Accordingly, the number of degree-days for the İpsala region can be taken as 2138 [9]. Based on this number of degree-days, the annual heating load for a greenhouse with a cover surface of 1000 $m^2$, which can be built in the İpsala region, has been calculated for the cases of using different cover materials. The technical data that form the basis of the calculations are given in Table 1, Table 2 and Table 3.

**Table 1:** Thermal resistances of greenhouse cover materials (Baytorun, 1995)

| Cover material | $R_\lambda$ ($m^2$ ℃/W) |
|---|---|
| Greenhouse glass | 0.01 |
| Hard plastic (1 mm thick) | 0.01 |
| Double glazing in steel frames (15 mm spacing) | 0.14 |
| Frameless double-layered rigid plastic (12 mm spacing) | 0.15 |
| Double-layer plastic (10 mm spacing) | 0.10 |
| Single ply plastic (0.2 mm) (PVC, PE) | 0.01 |

**Table 2:** Outer surface thermal resistance of greenhouse cover (Bailey, 1988)

| Situation of the greenhouse against the wind | $R_d$ (m$^2$ °C/W) |
|---|---|
| Protected | 0.070 |
| Normal | 0.045 |
| Open | 0.020 |

**Table 3:** Inner surface thermal resistance of greenhouse cover (Bailey, 1988)

| Heating system | $R_i$ (m$^2$ °C/W) |
|---|---|
| Heating pipes in the greenhouse floor | 0.12 |
| Air blowers from perforated ducts | 0.10 |

The use of heating pipes laid on the greenhouse floor for heating the greenhouse is common, especially in greenhouses where soilless agriculture is carried out. It is the most efficient and effective method among known heating methods. The required heat transmission coefficient (U) values for this heating method are calculated and given in Table 4.

**Table 4:** Uvalues in case the greenhouse is heated with heating pipes laid on the floor

| Cover material | U value (W/m$^2$°C) | | |
|---|---|---|---|
| | Situation of the greenhouse against the wind | | |
| | Protected | Normal | Open |
| Greenhouse glass | 5.0 | 5.7 | 6.7 |
| Hard plastic (1 mm thick) | 5.0 | 5.7 | 6.7 |
| Double glazing in steel frames (15 mm spacing) | 3.0 | 3.3 | 3.6 |
| Frameless double-layered rigid plastic (12 mm sp.) | 2.9 | 3.2 | 3.4 |
| Double-layer plastic (10 mm spacing) | 3.4 | 3.8 | 4.2 |
| Single ply plastic (0.2 mm) (PVC, PE) | 5.0 | 5.7 | 6.7 |

In case a greenhouse with a 1000 m$^2$ cover surface for the İpsala region is heated with pipes laid on the floor using the U values given in Table 4; the annual heat requirements were calculated according to the number of degree-days methods and are presented in Table 5.

**Table 5:** Annual heating load amounts

| Cover material | Heating load (W/yıl) | | |
|---|---|---|---|
| | Situation of the greenhouse against the wind | | |
| | Protected | Normal | Open |
| Greenhouse glass | 366514285 | 417826285 | 491129142 |
| Hard plastic (1 mm thick) | 366514285 | 417826285 | 491129142 |
| Double glazing in steel frames (15 mm sp) | 219908571 | 241899428 | 263890285 |
| Frameless double-layered rigid plastic (12mm sp.) | 212578285 | 234569142 | 249229714 |
| Double-layer plastic (10 mm spacing) | 249229714 | 278550857 | 307872000 |
| Single ply plastic (0.2 mm) (PVC, PE) | 366514285 | 417826285 | 491129142 |

Another commonly used method for heating greenhouses is the use of hot air blowers through perforated channels. The required heat transmission coefficient (U) values for this heating method were calculated and given in Table 6.

**Table 6:** U values in case of heating the greenhouse with hot air from perforated ducts

| Cover material | U value (W/m$^2$°C) | | |
|---|---|---|---|
| | Situation of the greenhouse against the wind | | |
| | Protected | Normal | Open |
| Greenhouse glass | 5.6 | 6.5 | 7.7 |
| Hard plastic (1 mm thick) | 5.6 | 6.5 | 7.7 |
| Double glazing in steel frames (15 mm sp) | 3.2 | 3.5 | 3.8 |
| Frameless double-layered rigid plastic (12mm sp.) | 3.1 | 3.4 | 3.7 |
| Double-layer plastic (10 mm spacing) | 3.7 | 4.1 | 4.5 |
| Single ply plastic (0.2 mm) (PVC, PE) | 5.6 | 6.5 | 7.7 |

In case a greenhouse with a 1000 $m^2$ cover surface for the İpsala region is heated with hot air through perforated channels using the U values given in Table 6; the annual heat requirements were calculated according to the number of degree-days method and are given in Table 7.

**Table 7:** Annual heating load amounts

| **Cover material** | **Heating load (W/yıl)** | | |
|---|---|---|---|
| | **Situation of the greenhouse against the wind** | | |
| | **Protected** | **Normal** | **Open** |
| Greenhouse glass | 410496000 | 476468571 | 564432000 |
| Hard plastic (1 mm thick) | 410496000 | 476468571 | 564432000 |
| Double glazing in steel frames (15 mm sp) | 234569142 | 256560000 | 278550857 |
| Frameless double-layered rigid plastic (12mm sp.) | 227238857 | 249229714 | 271220571 |
| Double-layer plastic (10 mm spacing) | 271220571 | 300541714 | 329862857 |
| Single ply plastic (0.2 mm) (PVC, PE) | 410496000 | 476468571 | 564432000 |

When the research data and the region's long-term observation findings are evaluated, it becomes clear that greenhouses must be heated to cultivate in them during the winter and transition seasons. When the values calculated according to the number of degree-days are examined, it is clear that the heating load will bring a high cost to the greenhouse enterprises. However, the widespread use of rough rice cultivation in the İpsala region and the use of husks released from the processing of rough rice as fuel can significantly reduce the greenhouse heating cost. The lower calorific value of rice husk is given as 3666.12 W/kg, and the upper calorific value is given as 3991.86 W/kg [12], [13]. In the Ipsala region, approximately 30000 tons of rice husk is produced annually, and approximately 165 decares of greenhouse can be heated based on this amount of husk and its average heating value.

## Conclusion

In order to minimize the heating load in the greenhouses to be built in the region, while choosing the greenhouse location, the areas not exposed to the cold winter winds facing south should be preferred as a topographic structure. In order to maximize solar energy utilization, single greenhouses should be situated east-west, whereas block greenhouses should be located south-north. For the local climate, the greenhouse's sidewall height should be between 2.0-3.0 m, and the roof inclination angle should be between 26°-30°. The covering material for greenhouses being built in the region should be double-layered glass or frameless double-layered rigid plastic in a steel frame with the highest thermal conductivity resistance. Heating pipes laid on the greenhouse floor or air blower systems from perforated channels should be used for heating greenhouses. Rice husks, primarily produced by processing the rough tice and have no economic value, can be used as fuel in heating.

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